

# Some Unique Superconductive Properties of Cuprates

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Copper oxides are the only materials that show transition temperatures,  $T_c$ , above the boiling point of liquid nitrogen, with a maximum  $T_c^m$  of 162 K under pressure. Their structure is layered, with one to several  $\text{CuO}_2$  planes, and upon hole doping, their transition temperature follows a dome-shaped curve with a maximum at  $T_c^m$ . In the underdoped regime, i.e., below  $T_c^m$ , a pseudogap  $T^*$  is found, with  $T^*$  always being larger than  $T_c$ , a property unique to the copper oxides.<sup>1</sup> In the superconducting state, Cooper pairs (two holes with antiparallel spins) are formed that exhibit coherence lengths on the order of a lattice distance in the  $\text{CuO}_2$  plane and one order of magnitude less perpendicular to it. Their macroscopic wave function is parallel to the  $\text{CuO}_2$  plane near 100 %  $d$  at their surface, but only 75 %  $d$  and 25 %  $s$  in the bulk, and near 100 %  $s$  perpendicular to the plane in YBCO. There are two gaps with the same  $T_c$  [2]. As a function of doping, the oxygen isotope effect is novel and can be quantitatively accounted for by a two-band vibronic

theory [3] near  $T_c^m$ , and underdoped below it till  $T_c = 0$  by a formula valid for (bi)polarons [4]. These cuprates are intrinsically heterogeneous in a dynamic way. In terms of quasiparticles, Jahn Teller bipolarons are present at low doping, and aggregate upon cooling [1], so that probably ramified clusters and/or stripes are formed, leading to a more Fermi-liquid-type behavior at large carrier concentrations above  $T_c^m$ .

## References

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<sup>1</sup>For an overview see [1].